Critical Factors in Testing MRAM Devices

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CYPRESS
Connecting From Last Mile To First Mile.™

SILICON
MAGNETIC
SYSTEMS

electroglas

Southwest Test Workshop

June 2003

Connecting From Last Mile To First Mile.™

AGENDA / OBJECTIVE

- MRAM Device ?
  - Nomenclature, Advantages, Applications
- MRAM Principles ?
  - Logic States, Read Ops, Write Ops
- Testing Challenges ?
  - KGD Test Flow
  - Device Tuning, Stray Mag Fields
  - How overcome?
    - (EG Prober, External Field Control Measures)
- Summary / Conclusions !

MRAM KEY POINTS

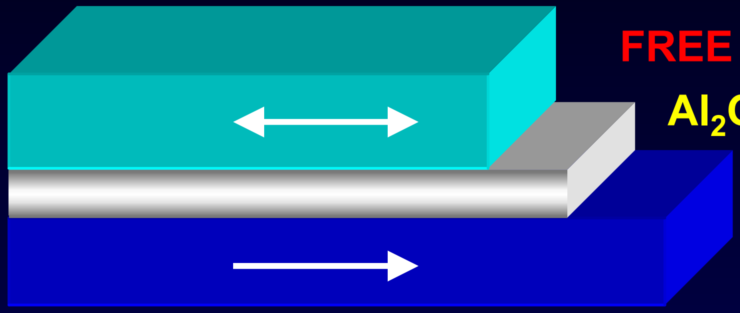
- Magnetoresistive Random Access Memory
  - Technology Marriage [CMOS + Mag Spin Layer]
  - DRAM Density
  - SRAM Speed
  - NVRAM Data Retention
- Key Aspects
  - Competitive Cell Size
  - High Write-cycle Endurance
  - Fast Write/Read Cycles
  - Data Retention Without Standby Power

EMERGING MEMORIES

- Perfect Memory ?
  - Low Cost (dense), Fast Data Access / Write, Low Power, Non-Volatile, CMOS compatible, Reliable
- New Technologies: FRAM, MRAM, OUM
- MRAM = Ideal Choice

◉ BEST ○ GOOD ● WORST	DRAM	SRAM	FLASH	FRAM	MRAM	OUM
COST	◉	●	○	○	○ / ◉	◉
ACCESS TIME	○	◉	○	○	◉	○
WRITE TIME	◉	◉	○	○	◉	○
ACTIVE POWER	◉	○	●	◉	◉	◉
STANDBY	●	○	◉	◉	◉	◉
NON-VOLATILE	●	●	◉	◉	◉	◉
ENDURANCE	◉	◉	●	○	◉	◉

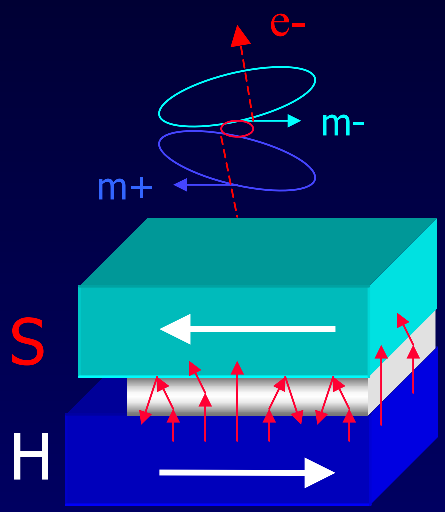
MTJ – SPINTRONIC STATES



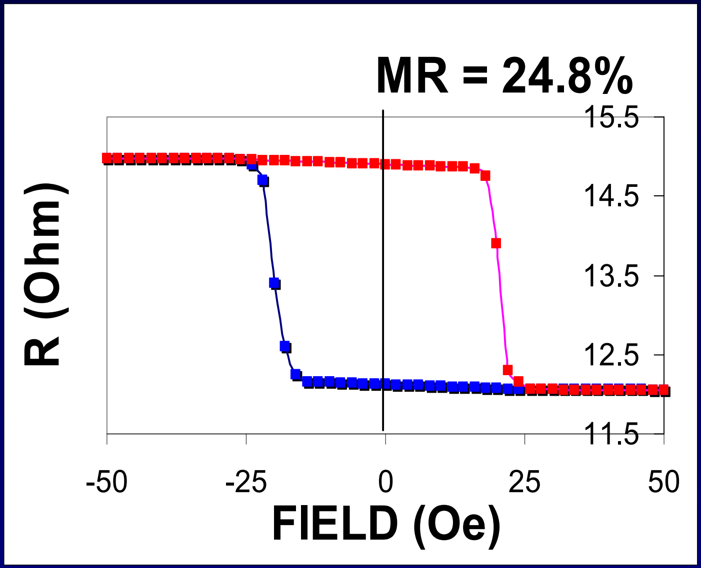
FREE (SOFT) LAYER

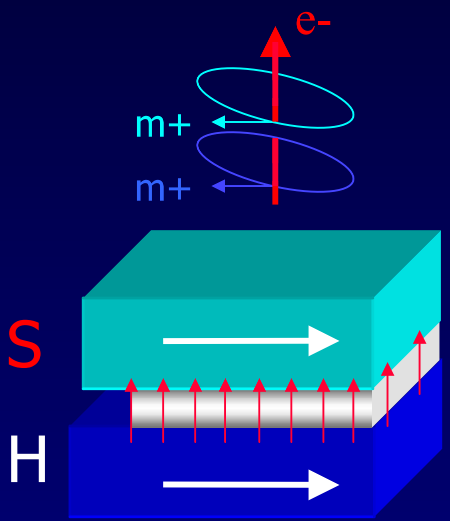
Al_2O_3 INSULATING BARRIER

PINNED (HARD) LAYER



ANTI- PARALLEL
Rap (High)
Logic State 1

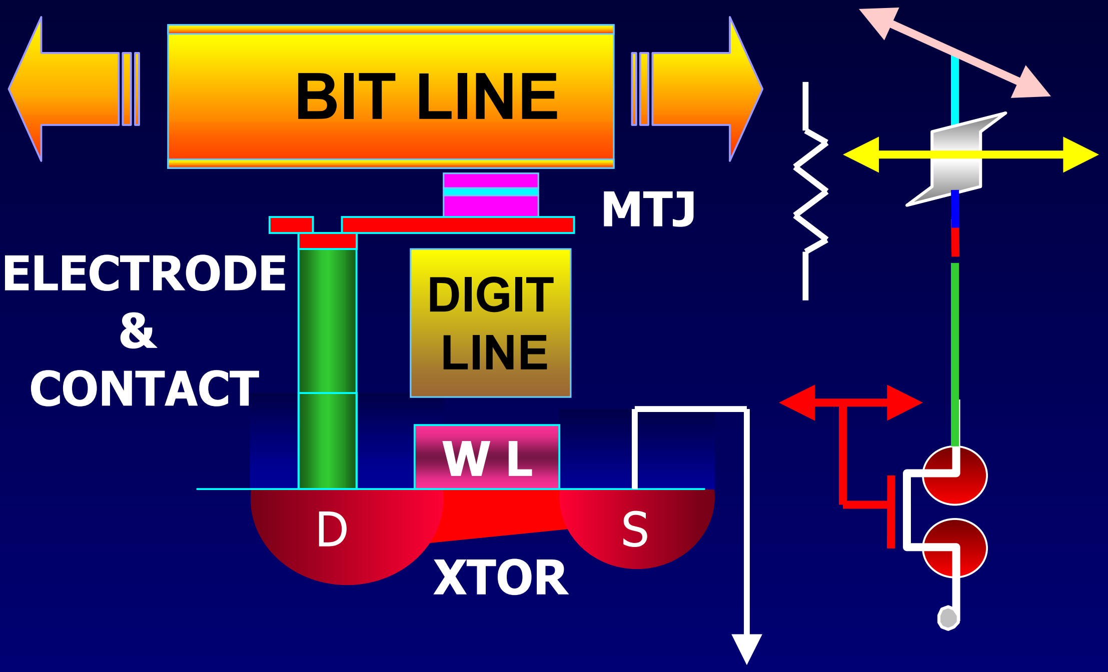




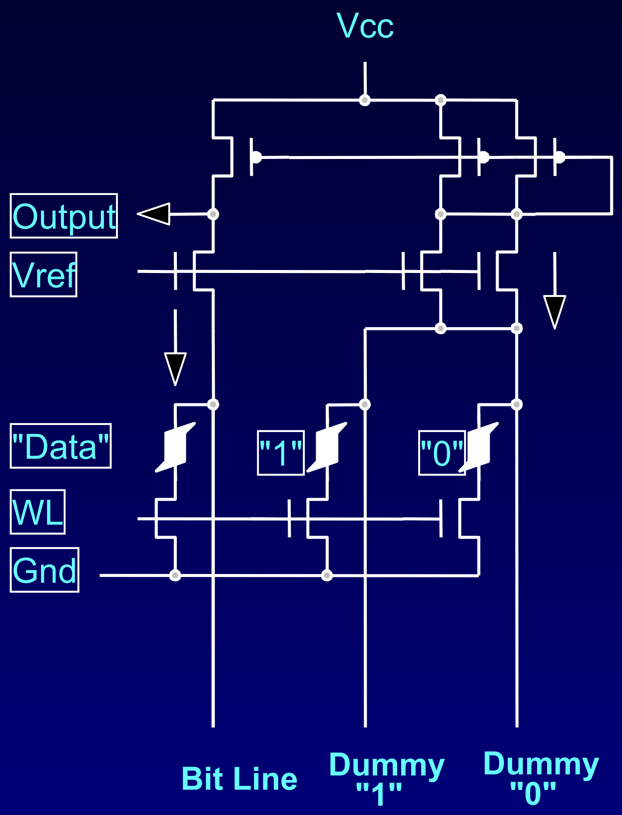
PARALLEL
Rp (Low)
Logic State 0

NON-DESTRUCTIVE READ

Read Resistance Of Selected 1T1R



Compare Resistance To Reference 1T1R*



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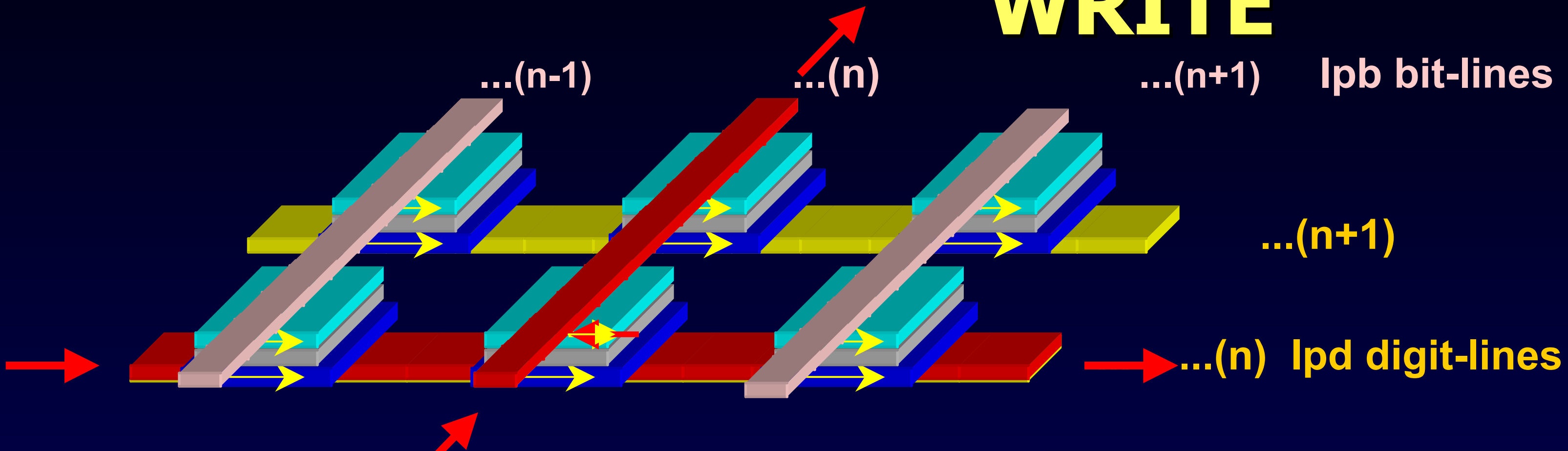
NON-DESTRUCTIVE WRITE

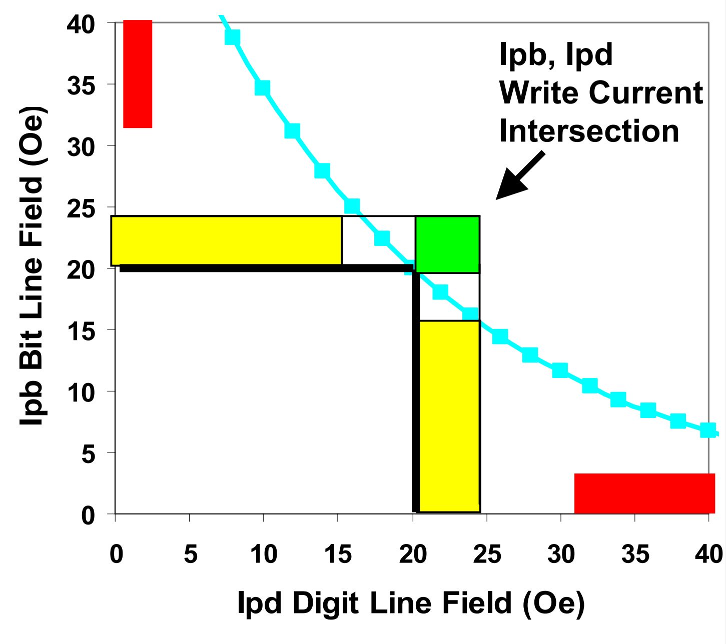


Ipb => Easy Axis (bitline)

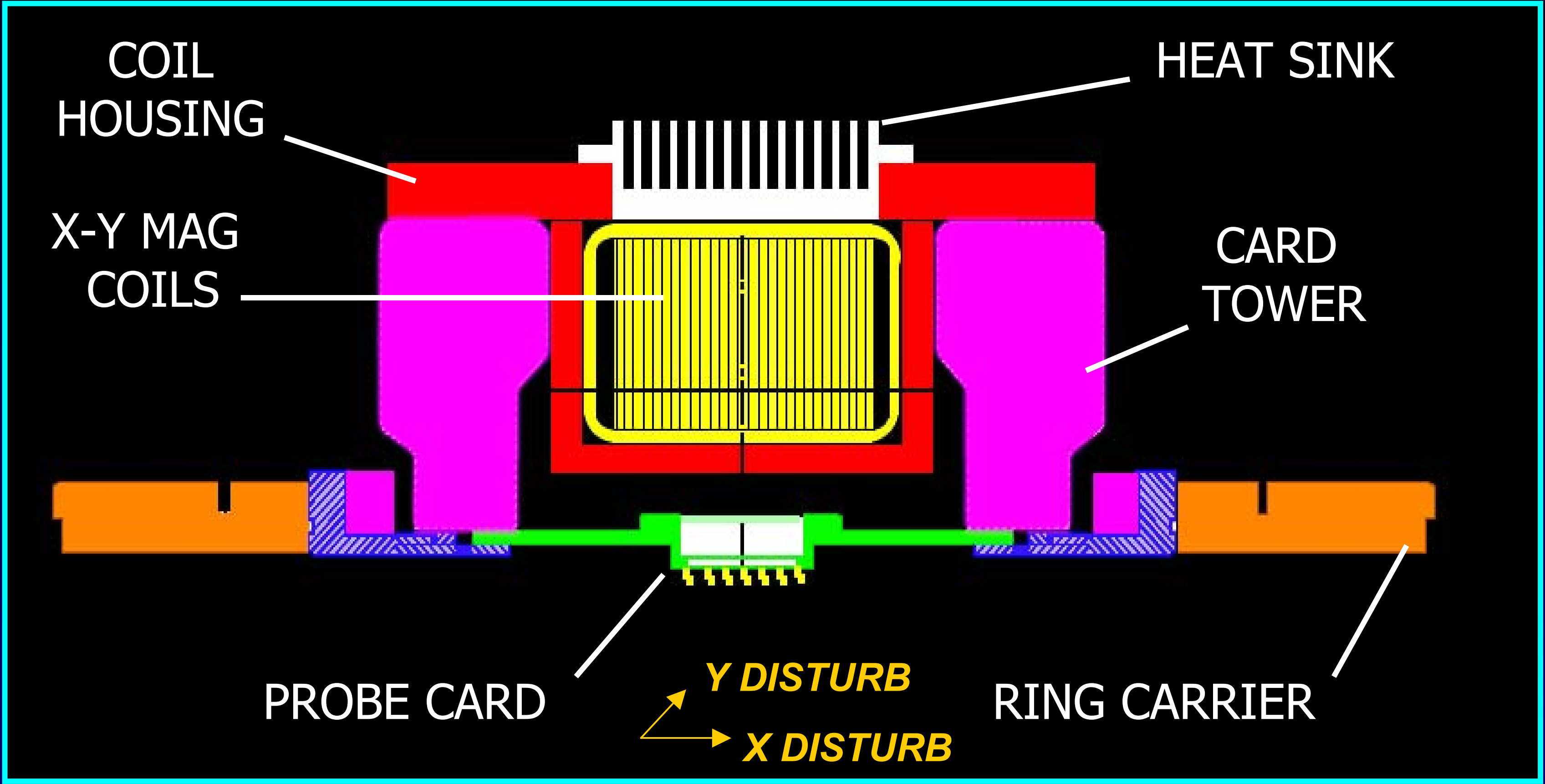
Ipd => Hard Axis (digit line)

Resultant Current = Ipd +Ipb

Only Intersection Gets Full Current



SORT MAG FIELD COILS



- Find Hyper-sensitive Bits –
  Sweep External XY Fields to Find > Repair / Kill

TEST CHALLENGES

- Scribeline Test
  - Standard IC tests: Transistor, Resistor, Contact, etc.
  - MRAM Adds Magnetic Switching

- Wafer Sort
  - Testing MRAM Is Similar to Testing SRAM
  - Adds Current Tuning & Disturb Tests at Sort-1
    - (Before Repair & Shielding)
  - Requires a Magnetically Neutral Environment
    - (< +/-1.0 Oe)
  - Produces a KGD device (WLBI, Class, etc.)

- Key Challenge
  - Magnetically Neutral Environment for Prober

MEASUREMENT UNITS

- $\vec{H}$ Magnetic Field Strength
  - CGS 1 oersted [Oe] – 2 poles @ 1cm -> 1 dyne
- $\vec{B}$ – Flux Density
  - # Flux Lines Passing Perpendicular to Given Area
  - CGS 1 gauss [G] – 1 flux lines / 1 cm2
  - SI 1 Tesla [T] – 10K flux lines / 1cm2
  - 1 G = 1 Oe in free space (air)
  - Earth’s Magnetic Field ~ 0.7 Gauss
  - Total Flux Density is RSS of X, Y, Z components

$$B = \sqrt{B_x^2 + B_y^2 + B_z^2}$$

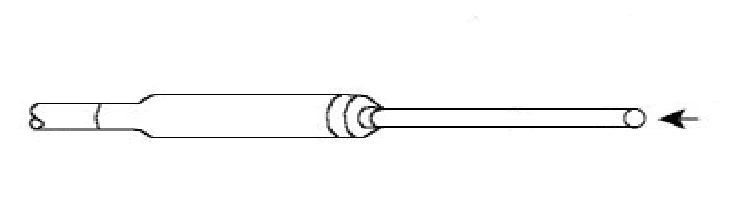
GAUSSMETERS

- F.W.Bell 1-axis, 2 Axis
- Lakeshore 2-axis
  - As Easy As Voltmeters
  - Hall Effect Devices

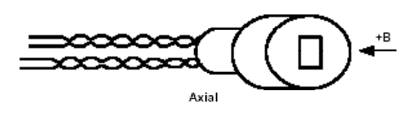
GAUSSMETERS

- Sources of Error
  - Drift - 1 Hour Warm up
  - Zeroing – Null in Zero Flux Chamber < -.004 G
  - Positioning – Probe Perpendicular to Surfaces
  - Temperature - Avoid High Temperature Areas
    Interference – Lab Equipment Audited, Max < .21G

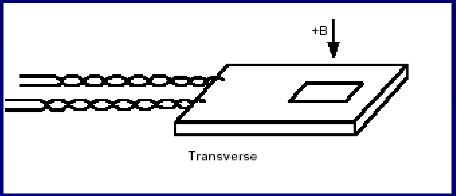
Probe



Axial



Transverse



MAGNETIC FIELD MEASUREMENTS

Engineering the Electroglas 4090µ Prober for a Neutral Magnetic Environment

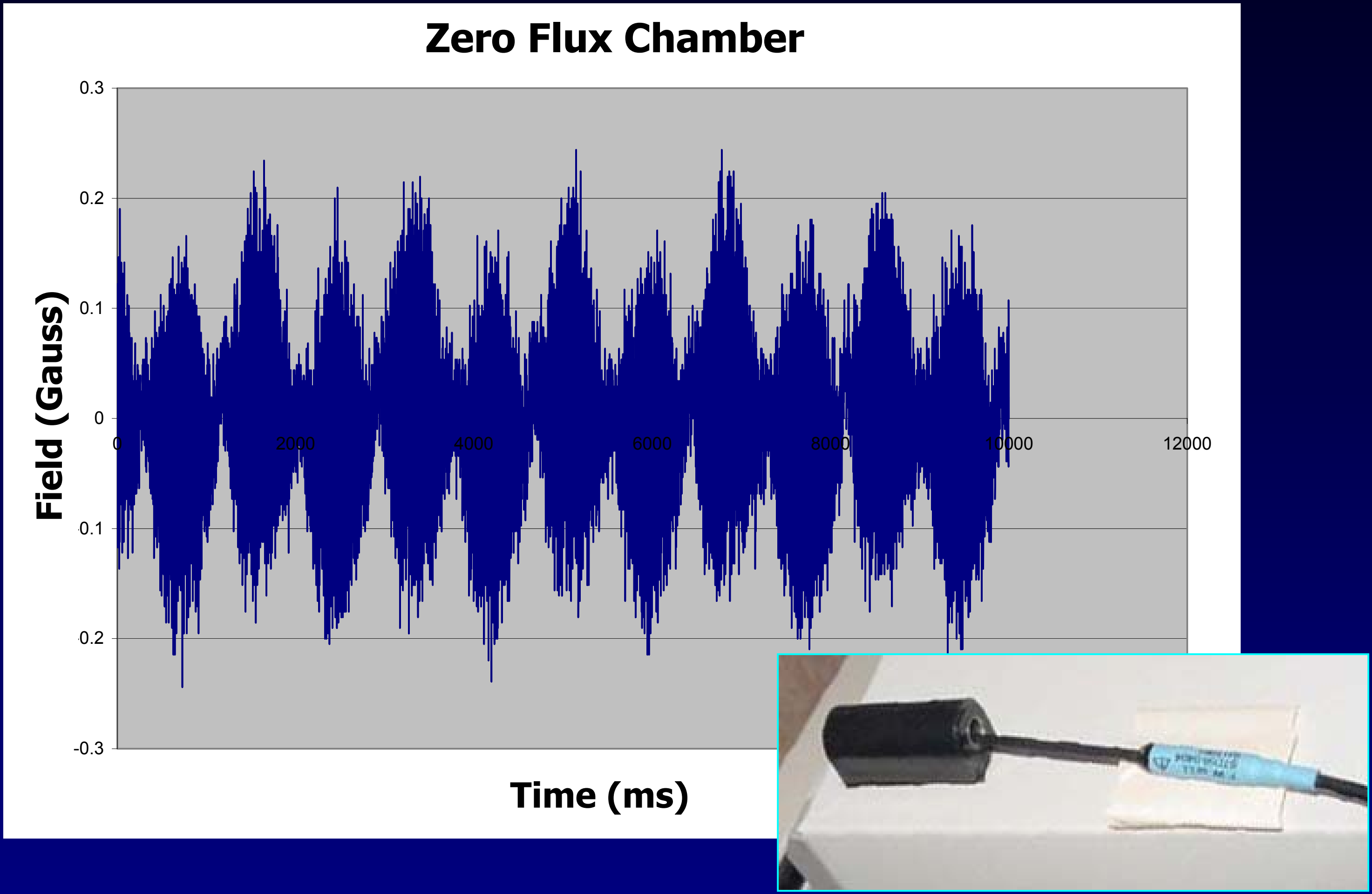
- Dynamic Analysis
  - Gaussmeter Noise
  - Z Motion
  - X,Y Motion
  - Temperature Transition
- Static Analysis
  - Chuck
  - Quick Loader
  - Transfer Arm
  - Pre-aligner
  - Lift Pins

DYNAMIC MEASUREMENTS

- Dynamic Measurements Made at 1000 Hz
- Analog-Out Signal Used
- Data Captured Using Test Point Software

NOISE LEVEL ANALYSIS

- Measured with probe in zero flux chamber



MOTION ANALYSIS

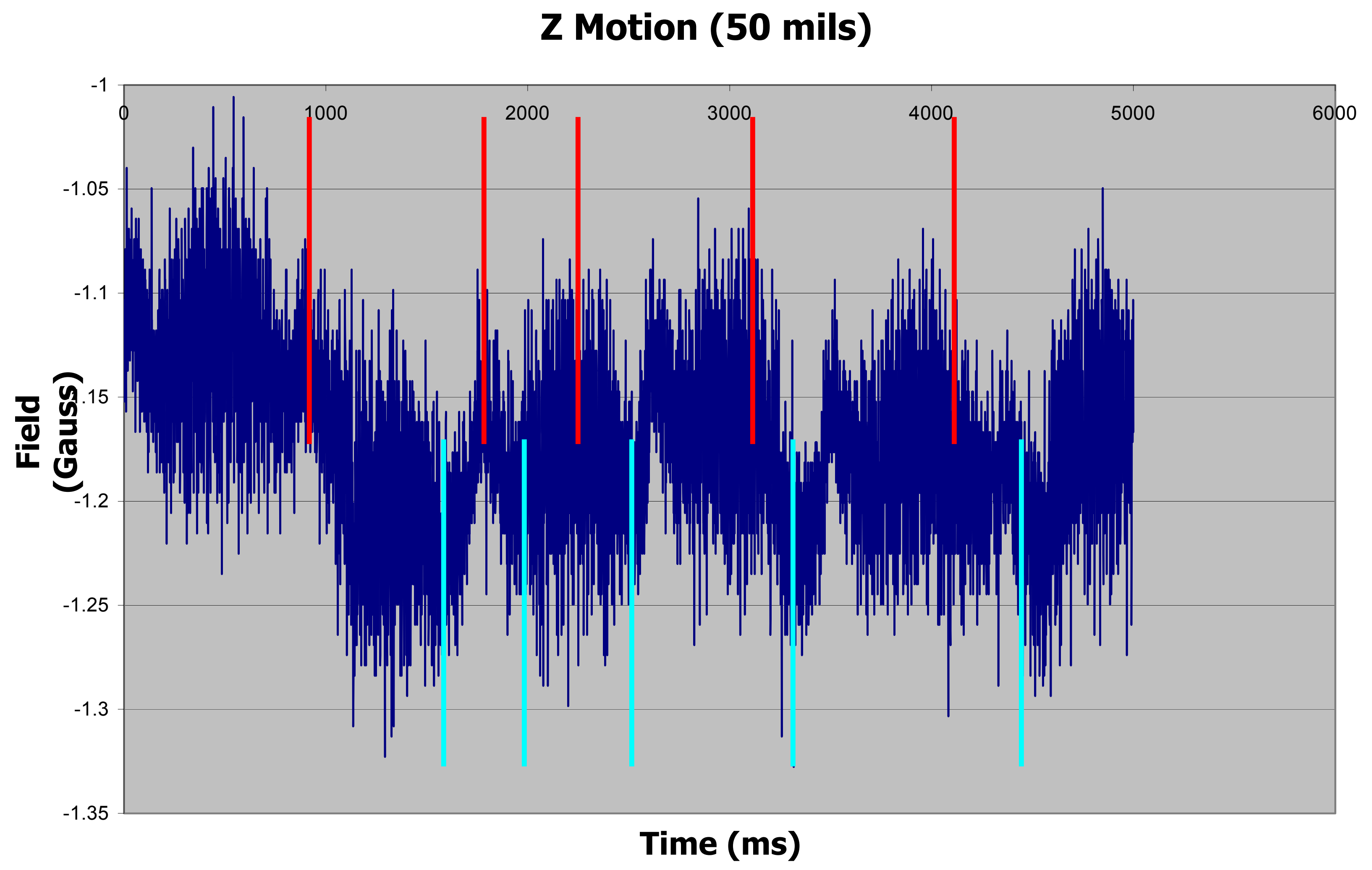
- Probe on Chuck Top (Wafer Plane on Forcer)
  - Proximal to Vacuum Pin
  - Field Component Normal to the Chuck Top

- Measurements Made for Z Motions:
  - 5 Mils,10 Mils, 20 Mils
  - 50 Mils, 200Mils – Data Shown

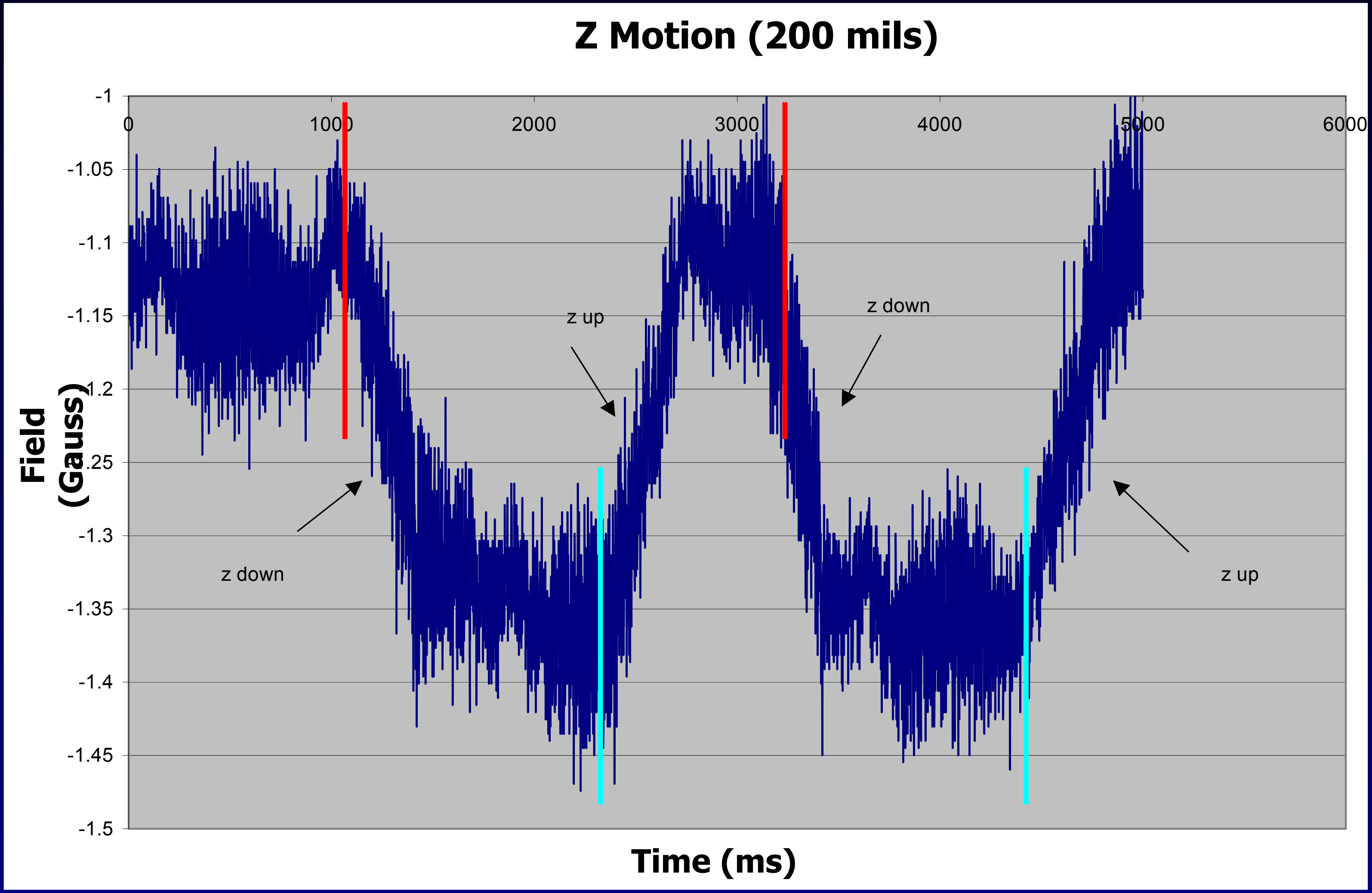
- Measurements Made for XY Platen Motions:
  - X-fast, X-slow, Y-fast, Y-slow

- Measurements Made for Temperature Change:
  - Ambient to Hot (25C to 125C) Peltier

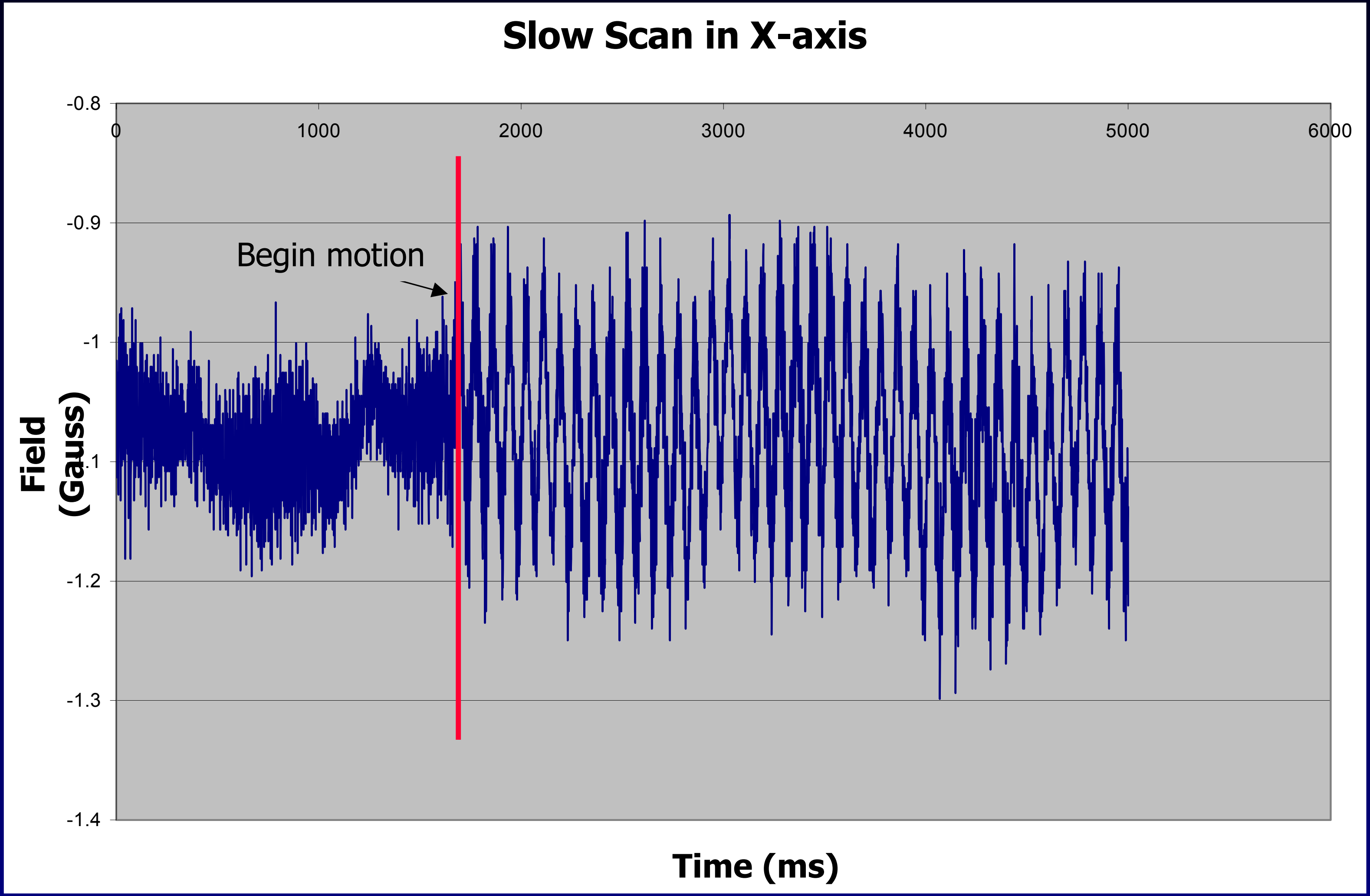
Z MOTION DATA – 50 MILS



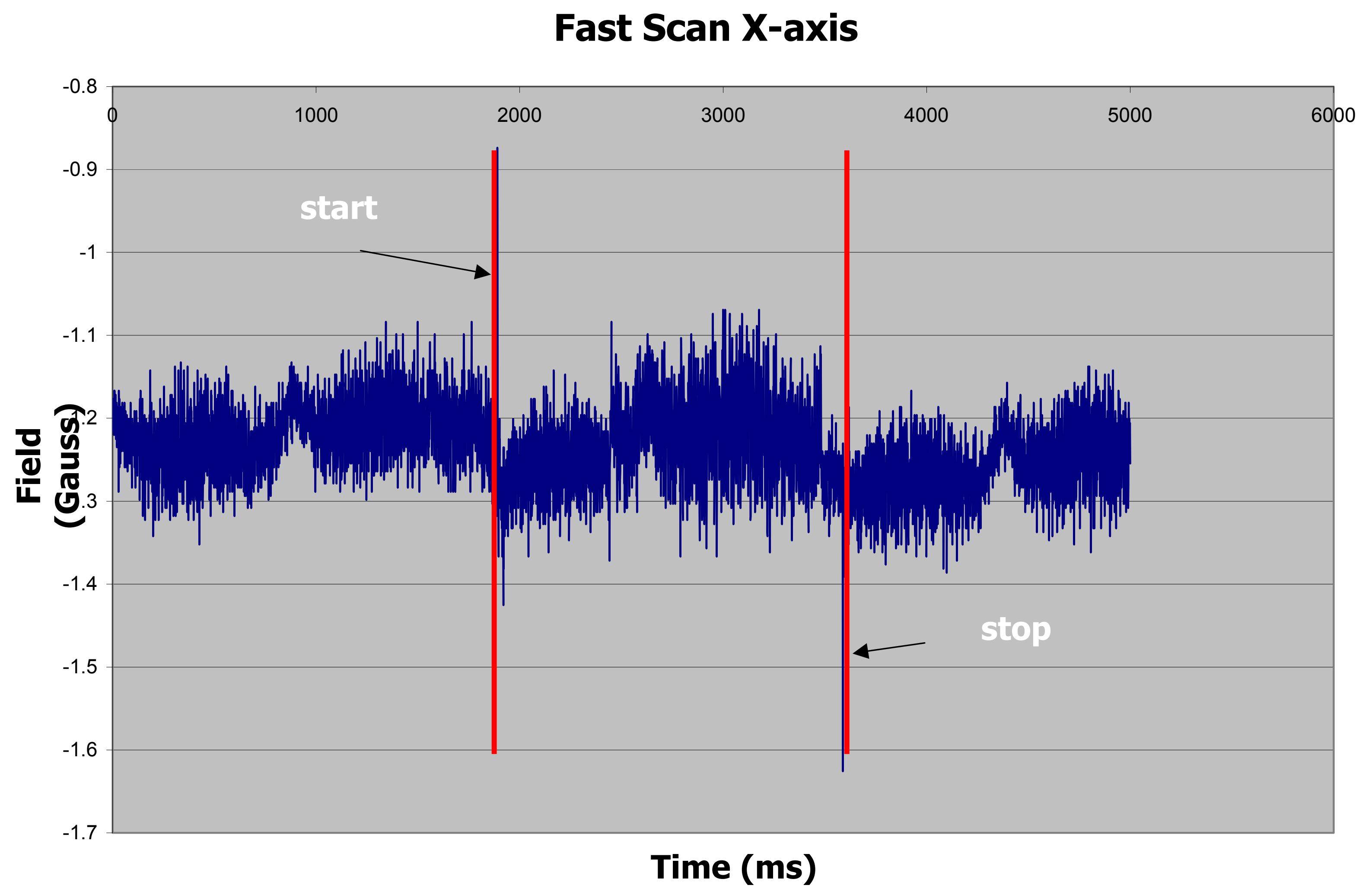
Z MOTION DATA – 200 MILS



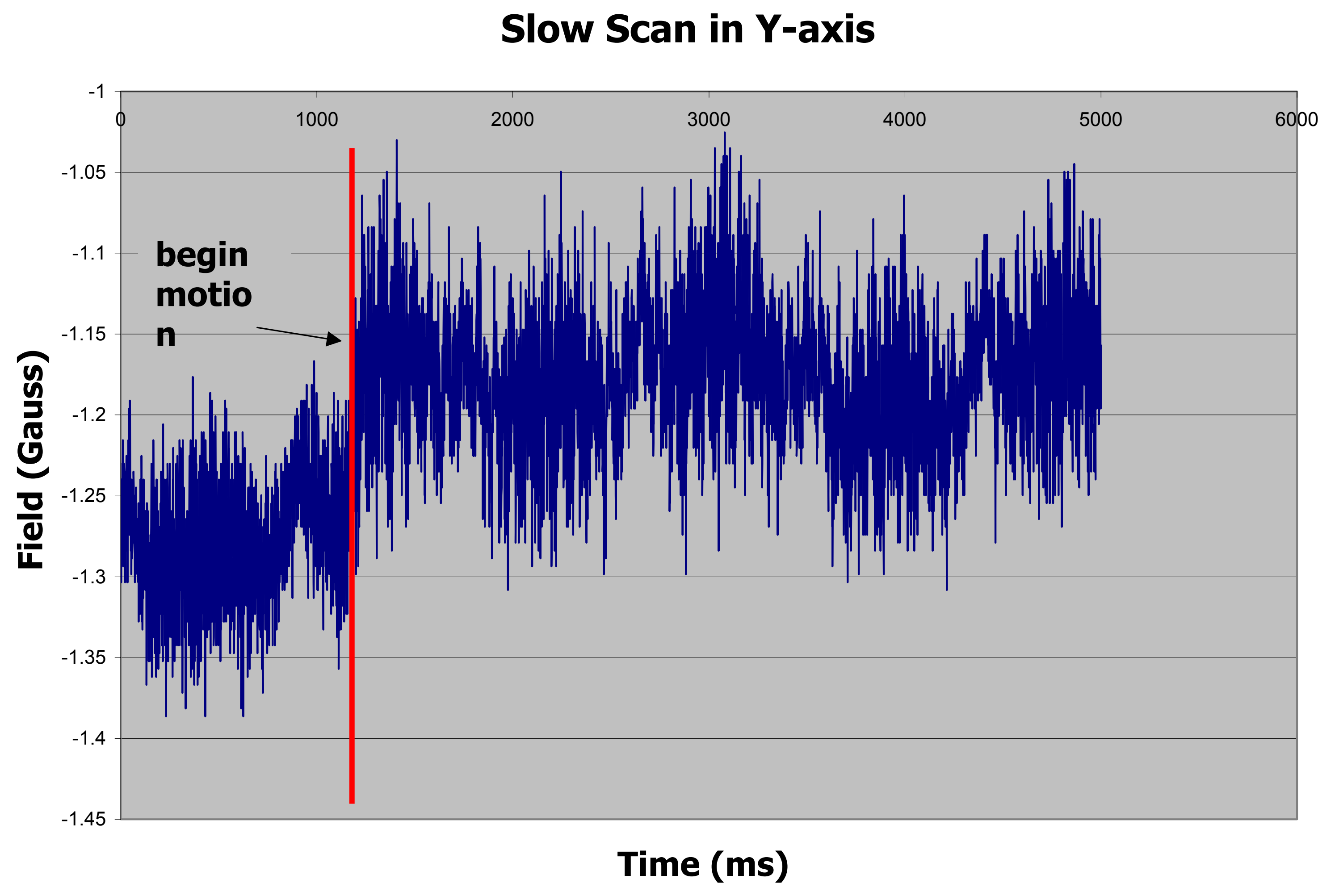
X MOTION SLOW SCAN



X MOTION FAST SCAN

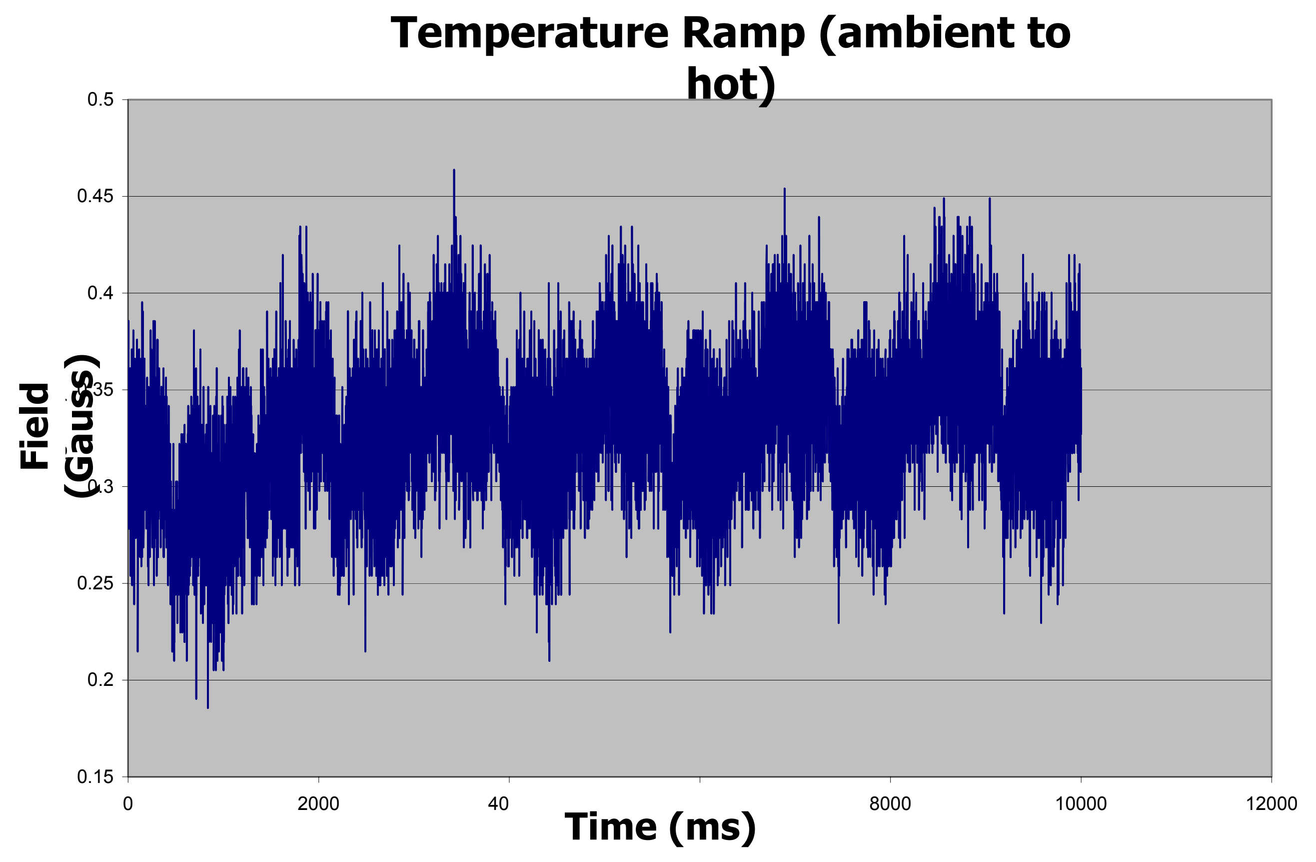


Y MOTION SLOW SCAN



TEMPERATURE TRANSITION ANALYSIS

- Initial Transition (10 Seconds) Ambient to Hot



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DYNAMIC RESULTS

Measurement	**MIN**	**AVE**	**MAX**	**IMPACT**
Zeroing		0.04		Noisy – Needs Improvement
Z - 5, 10, 15 mils	----	----	----	OK – Negligible
Z - 50 mils	-1.32	-1.15	-1.09	Shield
Z – 200 mils	-1.48	-1.23	-1.00	Shield
X-Slow Scan	-1.30	-1.08	-0.89	OK
X-Fast Scan	-1.42	-1.22	-1.07	OK
Y Scan	-1.38	----	-1.03	OK, Delta 0.18,
Temp	0.17	0.32	0.47	OK

Spec < 5 G for Dynamic

FIELD CONTAINMENT STEPS

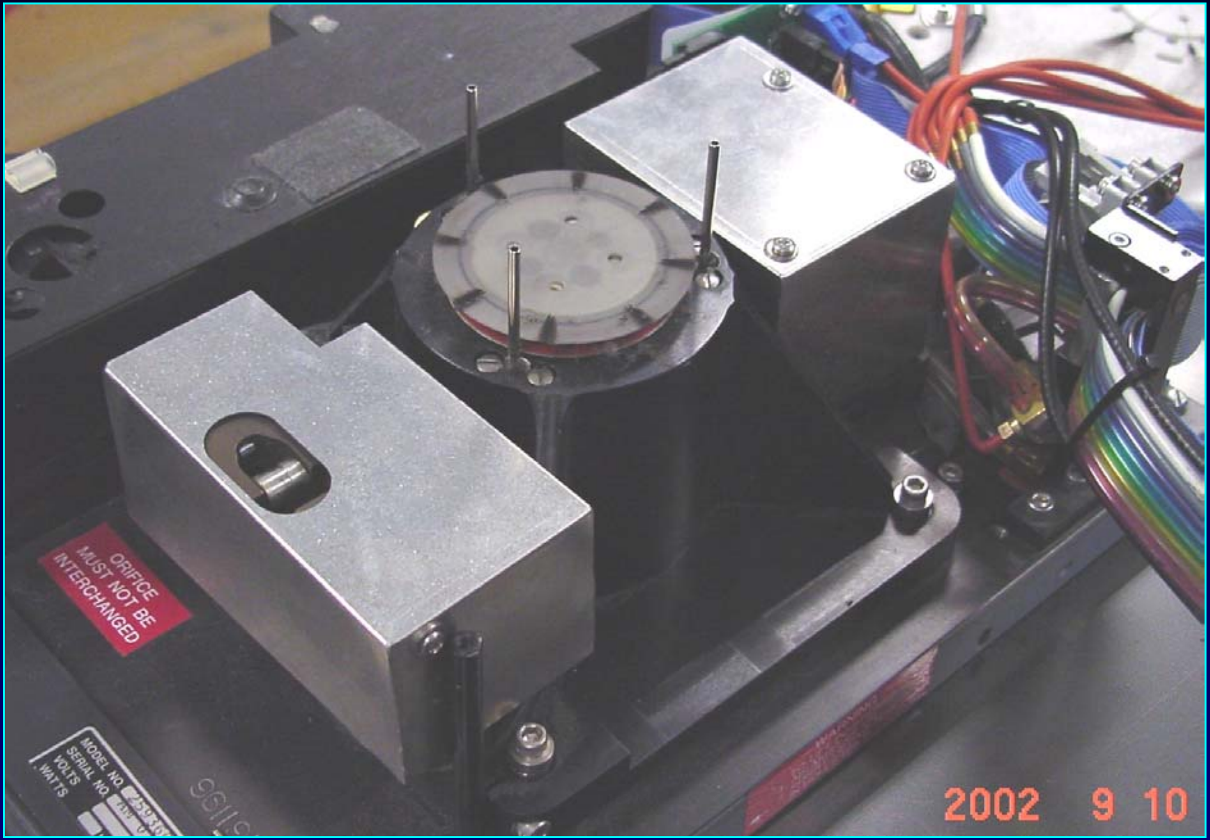
- Retrofitted Magnetic Shielding Kits
  - Replaced Shafts / Pins With Non-magnetic Materials
  - Designed Shields for Containment
  - Repositioned Components

- Improved Metrology –
  - Reduced Noisy Measurements
  - Improved Gaussmeters, Probes, and Sampling Jigs

- Completed Measurement Matrix

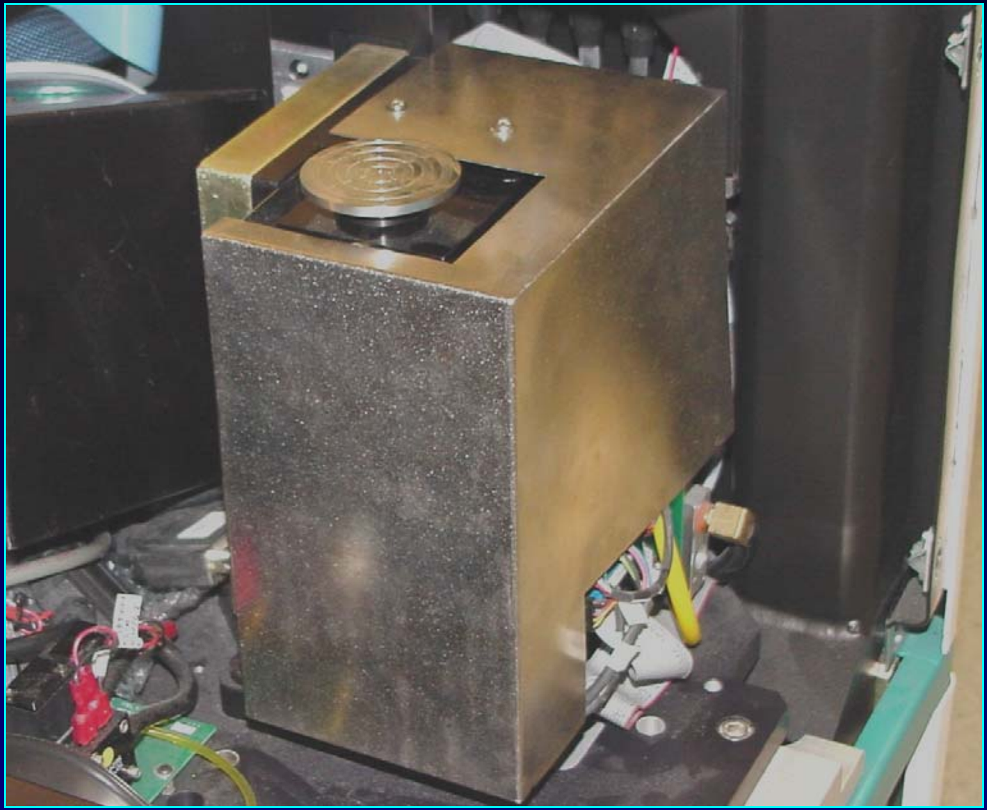
FORCER SHIELDS

Fully Assembled Theta and Z-motor Shield

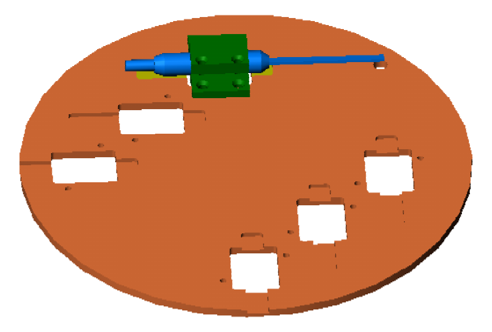


PRE-ALIGNER SHIELDS

Pre-Aligner Shield

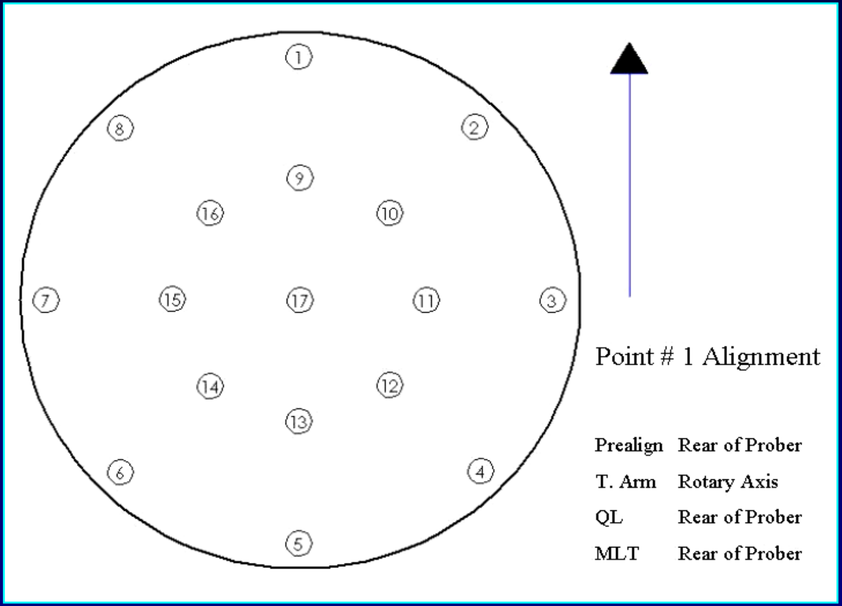


STATIC SAMPLING POINTS



SIMULATED WAFER

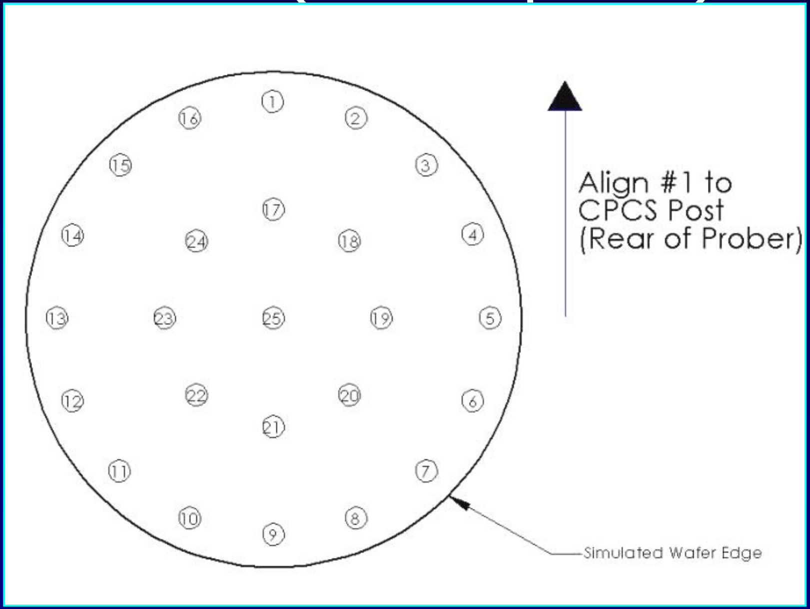
PREALIGNER (17 test points)



Point # 1 Alignment

Prealign	Rear of Prober
T. Arm	Rotary Axis
QL	Rear of Prober
MLT	Rear of Prober

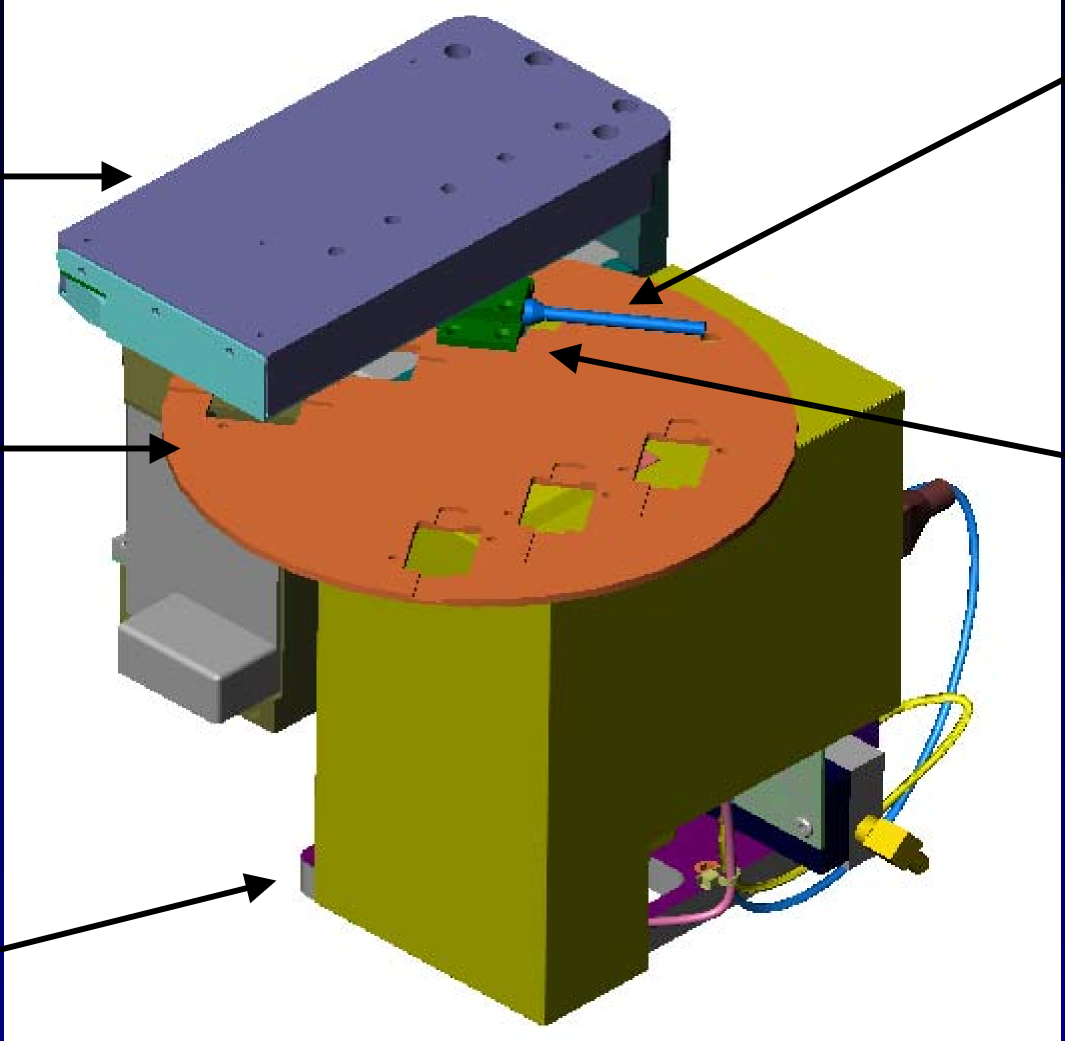
CHUCK (25 test points)



Align #1 to CPCS Post (Rear of Prober)

Simulated Wafer Edge

TEST FIXTURE



Prealigner Assy.

Simulated Wafer

Prealigner Cover

Sypris SAF99-1802 XY fields

Sypris STF99-0402 XYZ fields

Probe Holder

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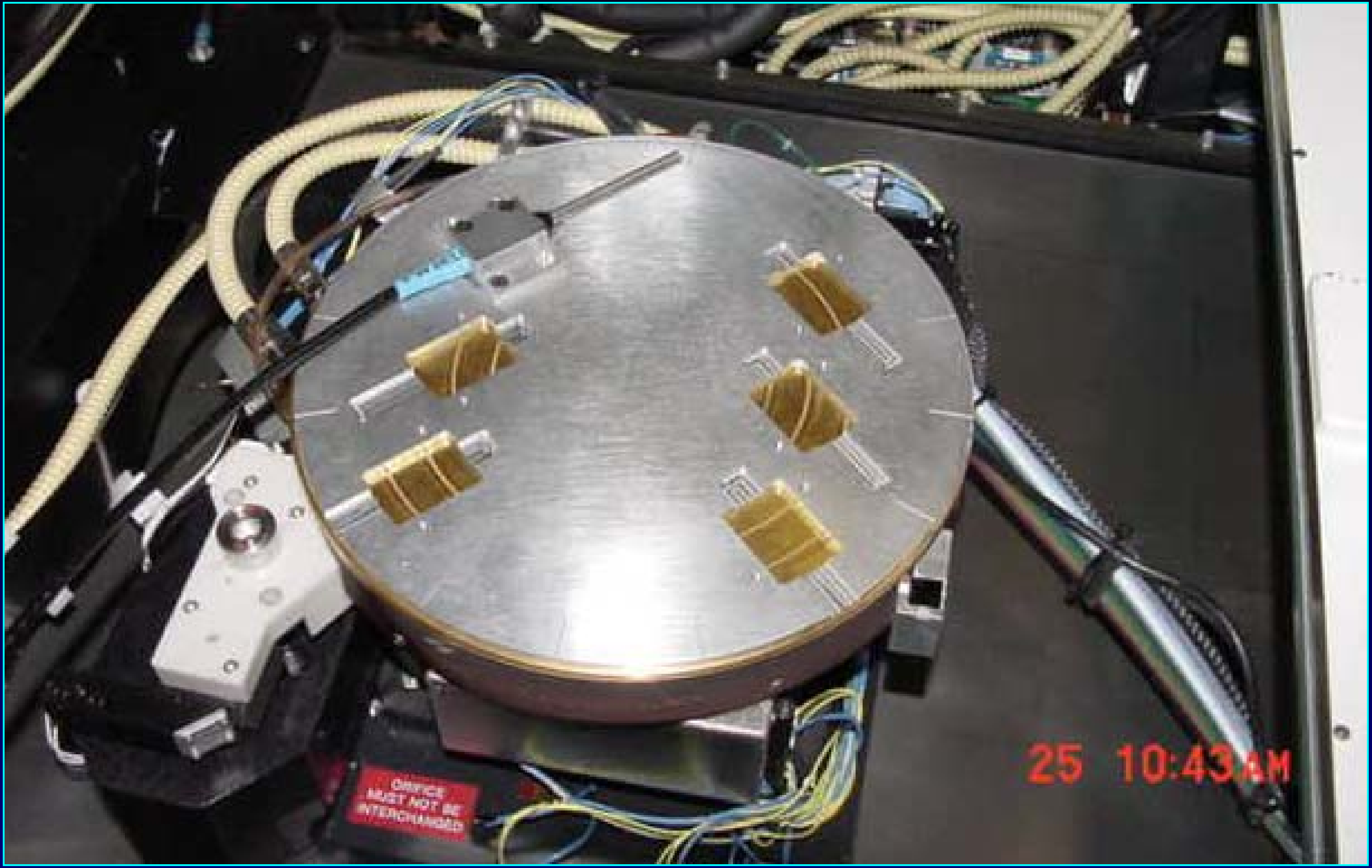
CHUCK FORCER POSITION



STATIC FIELD - CHUCK

- Measured (X, Y, and Z Axes)
  - Field Magnitude Is the Resultant Vector:

$$B = \sqrt{B_x^2 + B_y^2 + B_z^2}$$

- Results:
  - 1st Pass – Original Pins – 2.6 G Maximum
    - Pins Coupled Z, θ Motors to Wafer Surface
    - Replaced Pins With Non-magnetic Composition
  - 2nd Pass – SS 304 Pins – 1.84 G Maximum
  - 3rd Pass – New Mat'l Pins – 1.18 G Maximum
  - 4th Pass – Add Shields < 0.6 G Maximum

PIN MATERIAL EXPERIMENT

ss 304 pins (2nd Gen)

	1	2	3
Bx	0.55	-0.24	0.08
By	0.70	0.46	1.00
Bz	1.24	1.76	-0.30
B	1.53	1.84	1.05

Coupling Impact

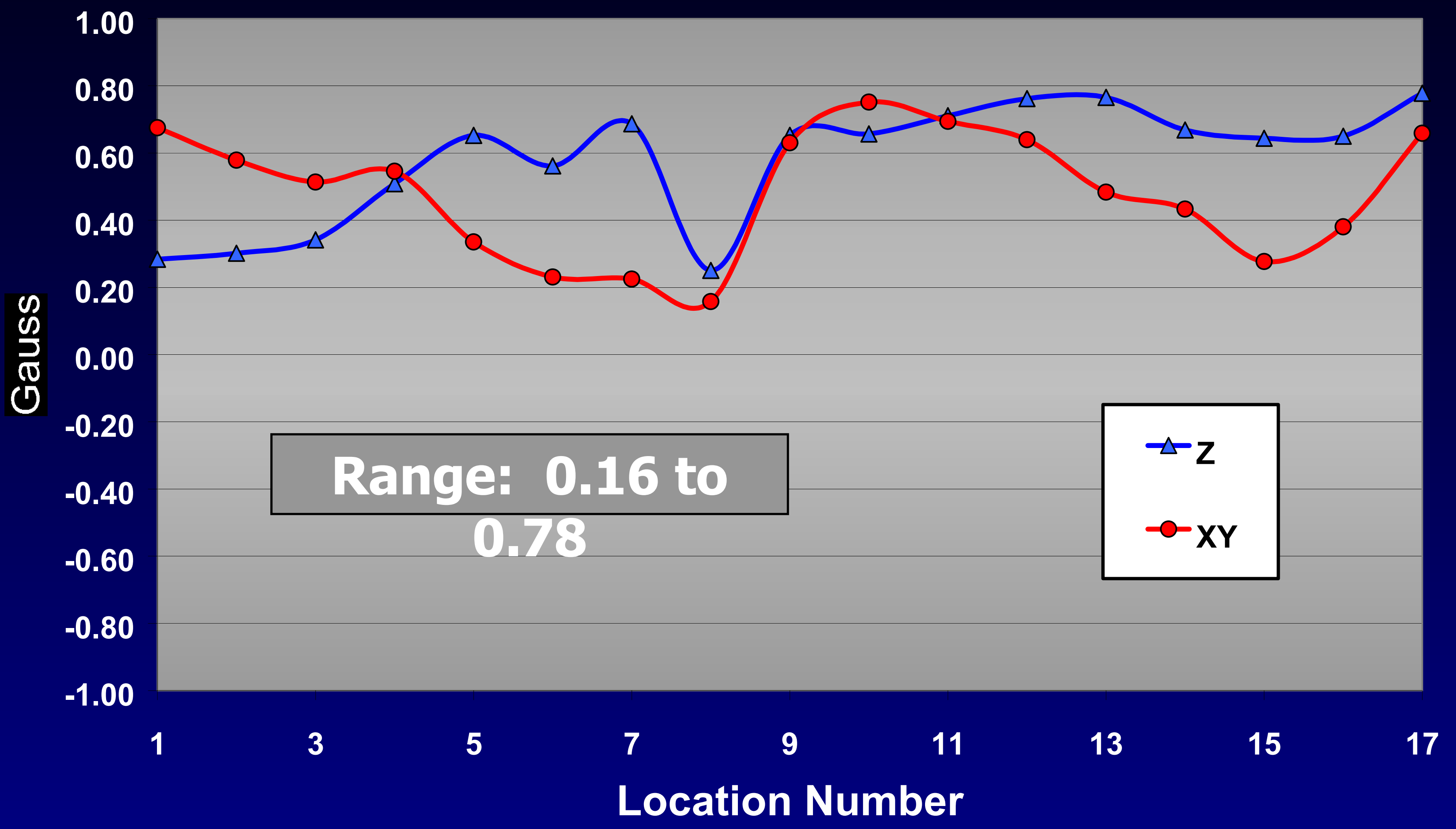
New Pins (3rd Gen)

	1	2	3
Bx	0.28	0.37	0.06
By	0.33	0.48	0.70
Bz	0.25	0.64	-0.95
B	0.50	0.88	1.18

None Z- θ Z- θ

- Decision:
  - Pins alone don't meet spec, shield Z-theta motors
  - After Shielding: Wafer Plane < 0.6 G, Meets Spec !

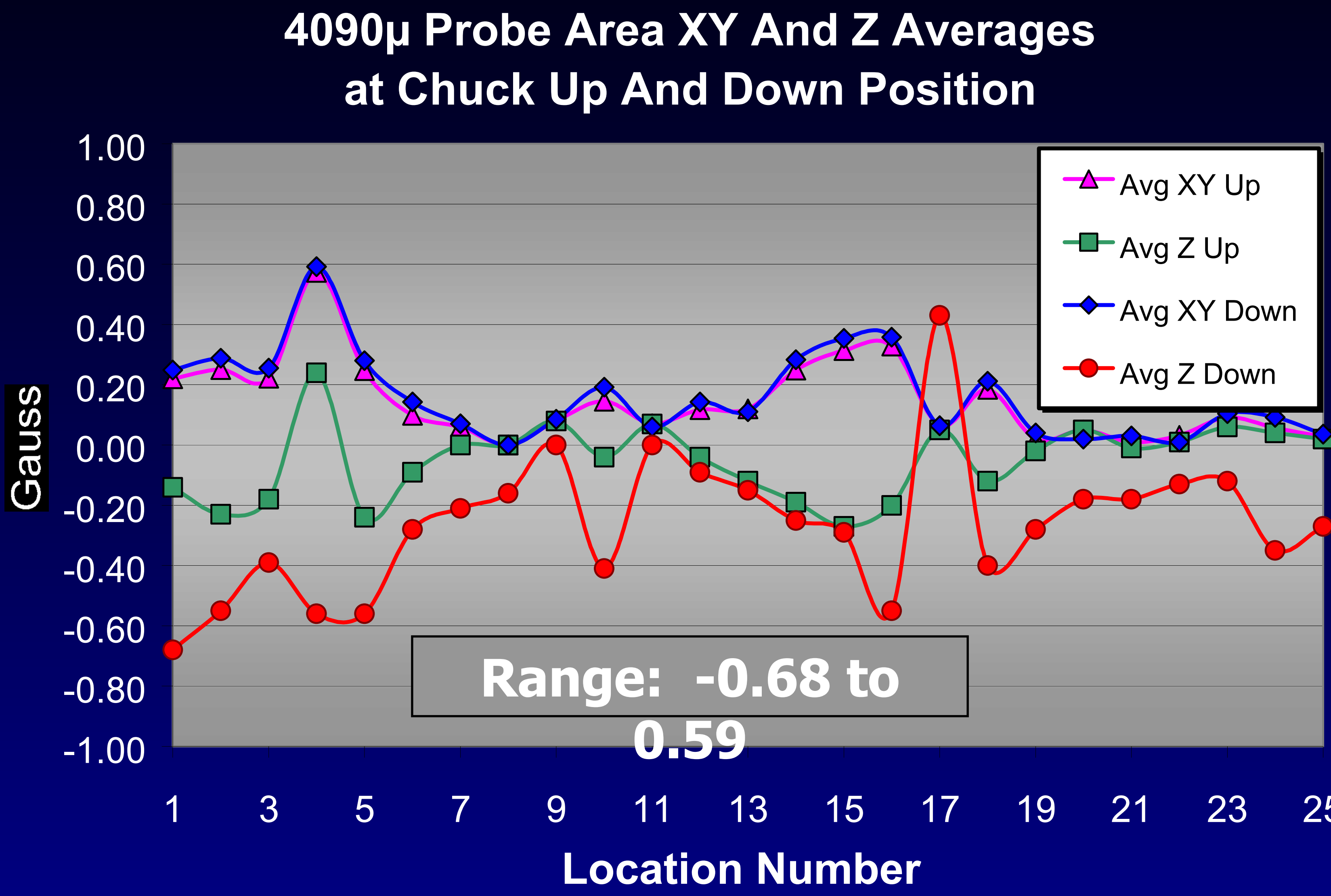
PRE-ALIGNER



4090µ Pre-aligner XY and Z Fields

Range: 0.16 to 0.78

FORCER – PROBE AREA



Range: -0.68 to 0.59

MATERIAL HANDLER

- Static Analysis
    - (measured over wafer surface)

Site	Before, Max	After, Max
Chuck	8.0	0.6
Quick Loader	0.5	0.5
Transfer arm	0.5	0.5
Pre-aligner	1.3	0.8
Lift pins	8.0	0.5

CONCLUSION / SUMMARY

- New Memory – New Requirements

- MRAM Advantages
  - Target applications - cellular phones, portable devices, and personal computers.
  - Instant-on computing, indefinite standby without power.

- Test Challenges
  - Accurate magnetic measurements
  - Control of stray magnetic fields

APPRECIATION

- Electroglas
  - Steve Lugosi
  - Larry Hendler
  - Robert Bergan
  - Hardip Singh
- Test Point Software
  - Larry Hendler
- Cypress - SMS
  - Narayan Pirohit
  - Fred Jenne